

# Radio Occultation Results from MarCO, The First Interplanetary CubeSat Mission

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# Outline

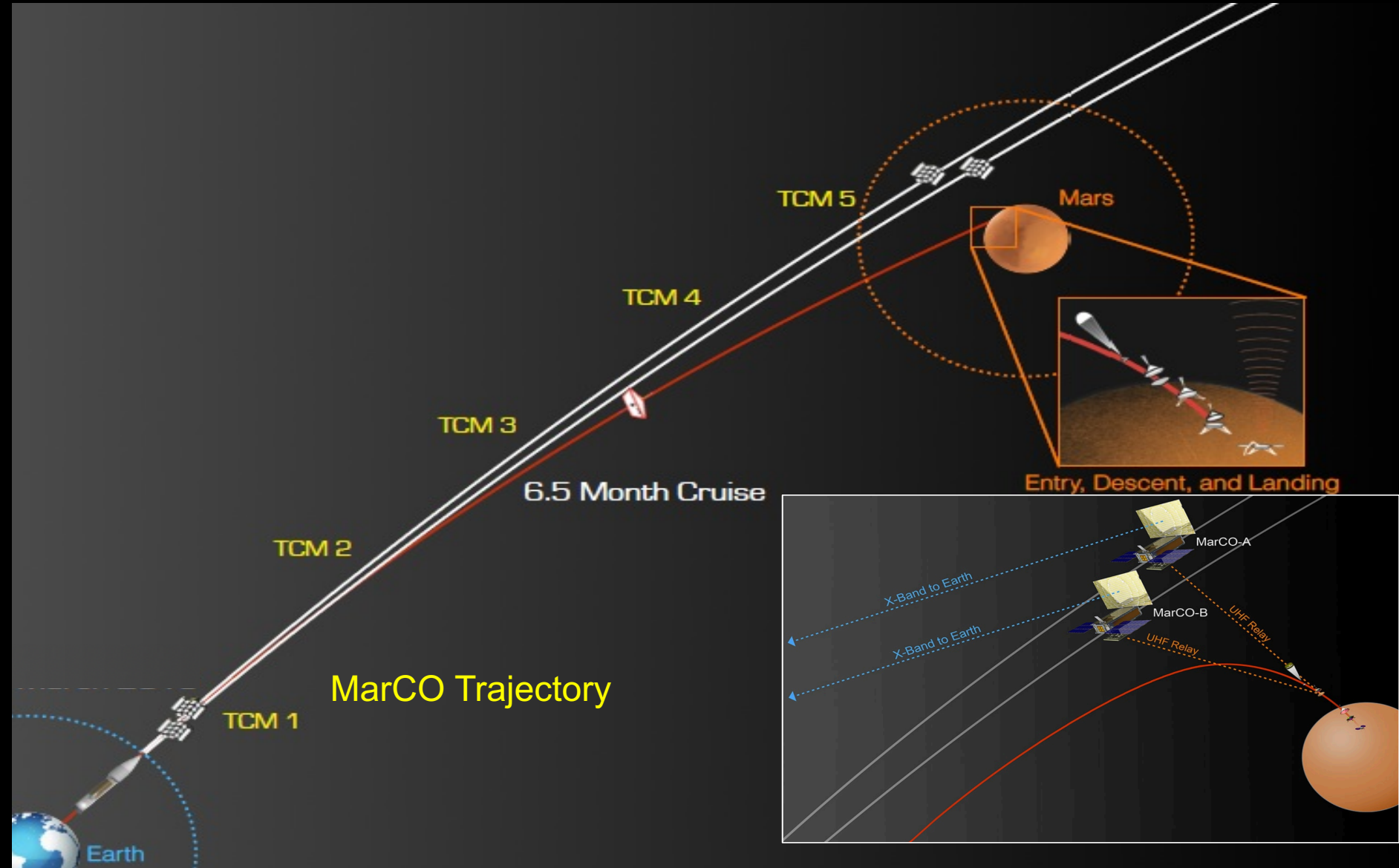


- Introduction – MarCO Mission
- MarCO Radio Communication
- MarCO Radio Occultation Performance Analysis
- Investigation of Future Planetary Science Missions using CubSats.
- Summary

# Introduction – MarCO Mission



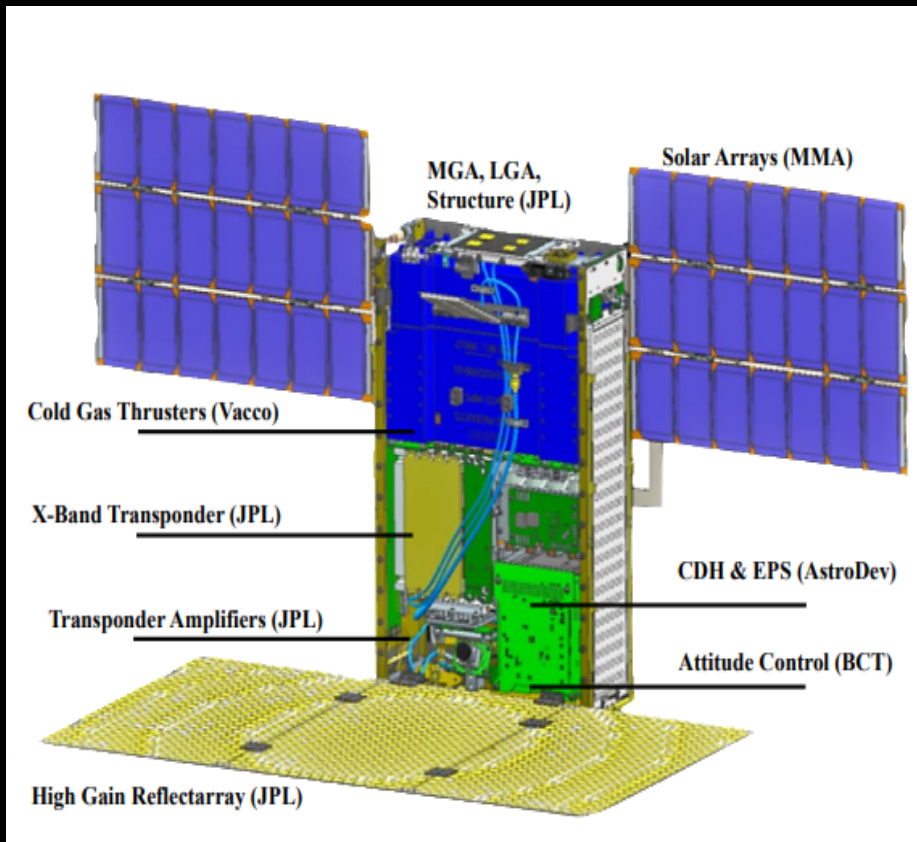
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# MarCO Radio Communication



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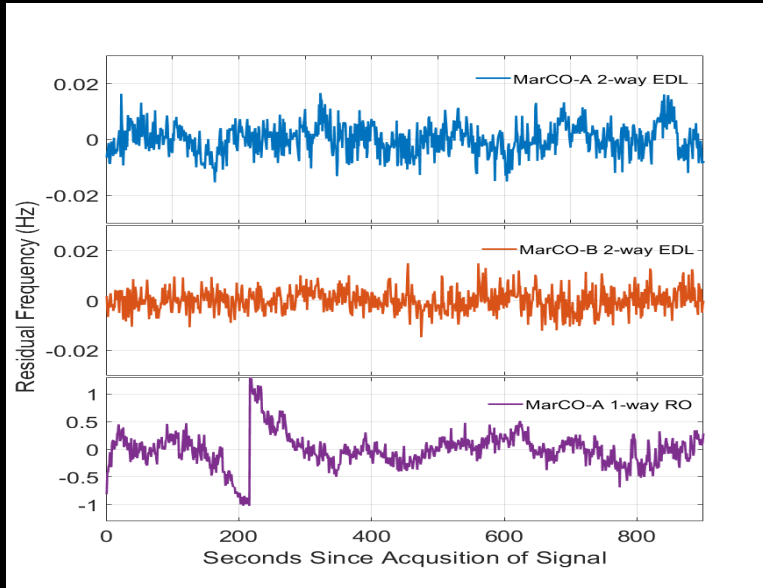
Noise sources on the MarCO radio link include:

- Ground equipment:
  - Frequency and Timing System noise
  - Antenna mechanical noise
- Spacecraft equipment:
  - Auxiliary Oscillator Stability
  - Translator Noise
  - Spacecraft Pointing
- Propagation effects:
  - Plasma noise (from Sun)
  - Earth Ionosphere delay
  - Earth troposphere noise

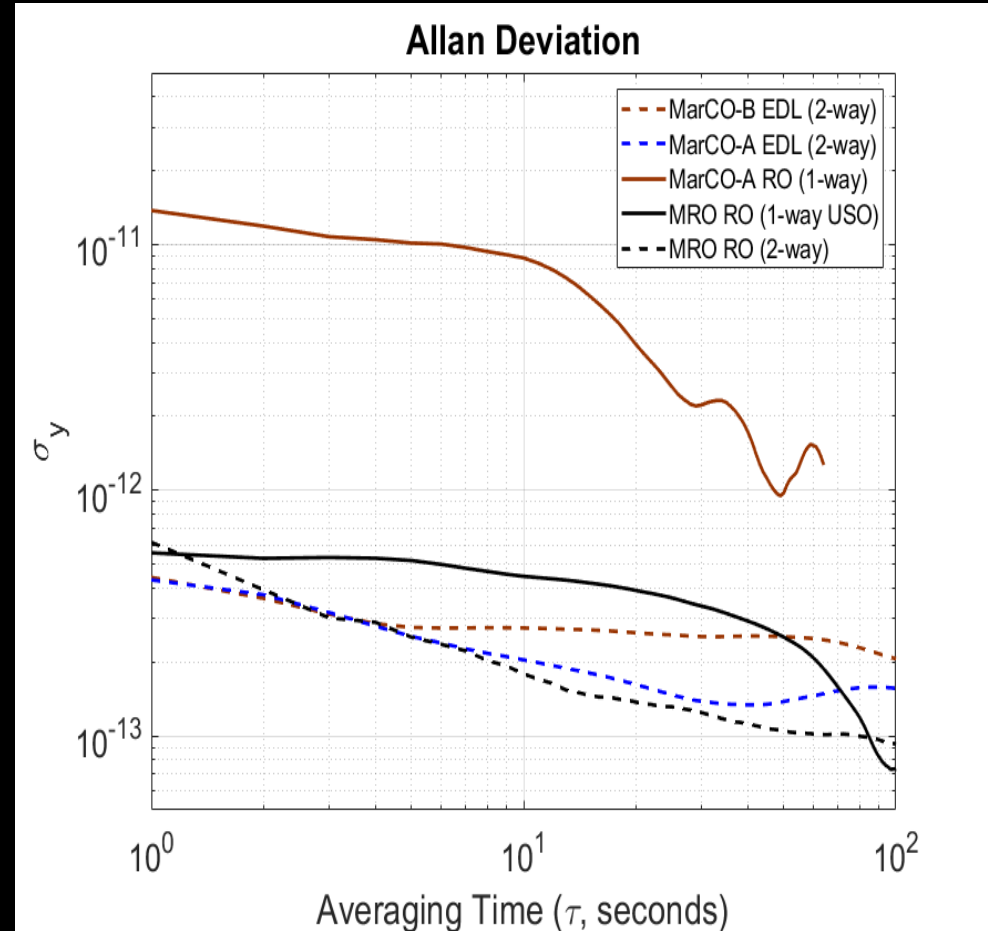
# Analysis of MarCO Radio Science Measurement Uncertainties



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Operational Phase	Tracking Mode	STD (Hz)
InSight AEDL		
MarCO-B	2-way	0.005
MarCO-A	2-way	0.004
Radio Occultation		
MarCO-A	1-way	0.42



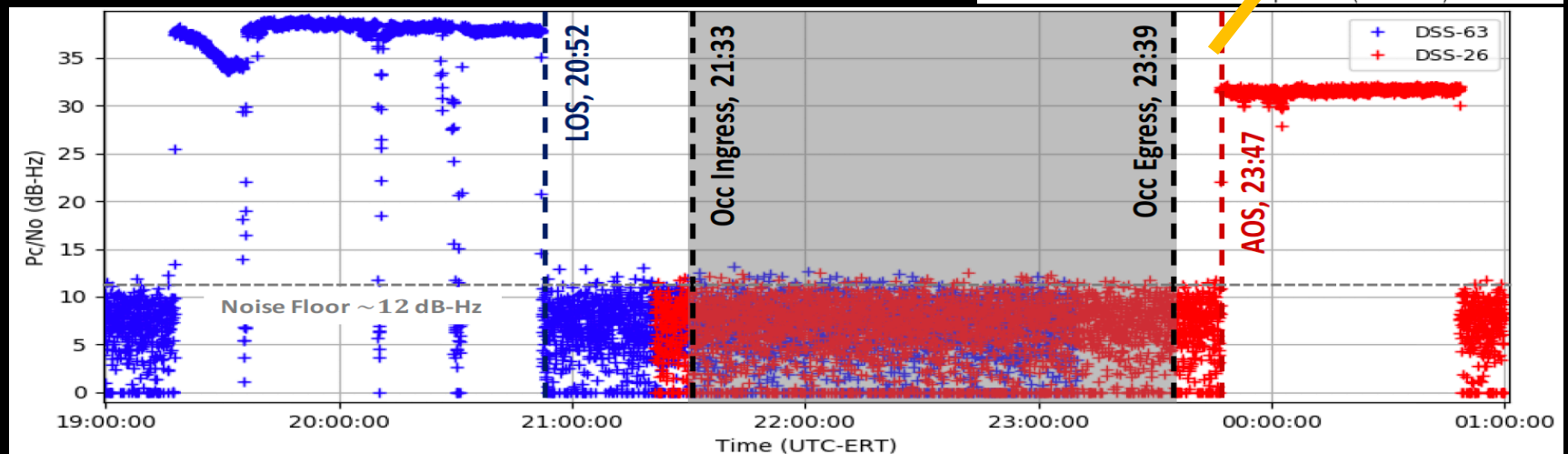
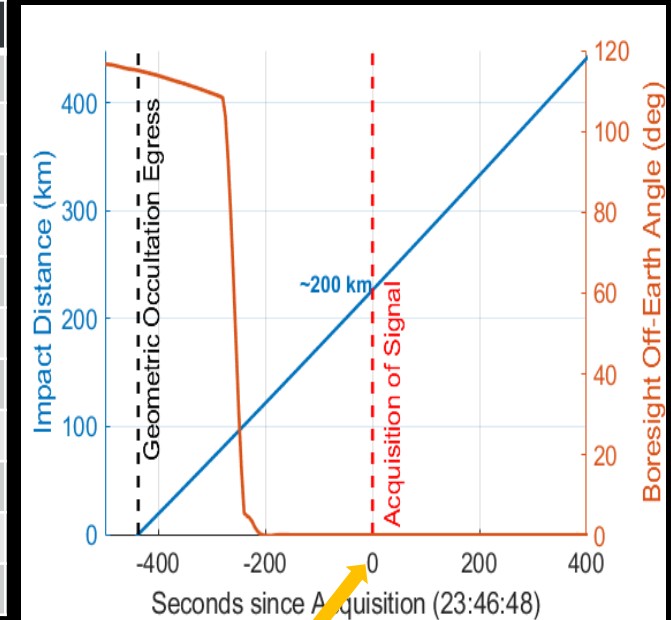


# MarCO Radio Occultation Experiment



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Time (UTC-ERT)	Event
14:15:00	Begin Open-Loop Recordings
19:17:48	DSS-63 Acquisition
19:53:09	InSight Landing
20:51:56	Turn Away from Earth-Point
20:52:00	DSS-63 Loss of Signal
21:33:19	Geometric Occultation Ingress
23:43:07	Turn to Earth-Point
23:39:09	Geometric Occultation Egress
23:46:48	DSS-26 Acquisition, 1-Way
00:48:10	DSS-26 Loss of Signal
01:00:00	End Open-Loop Recordings

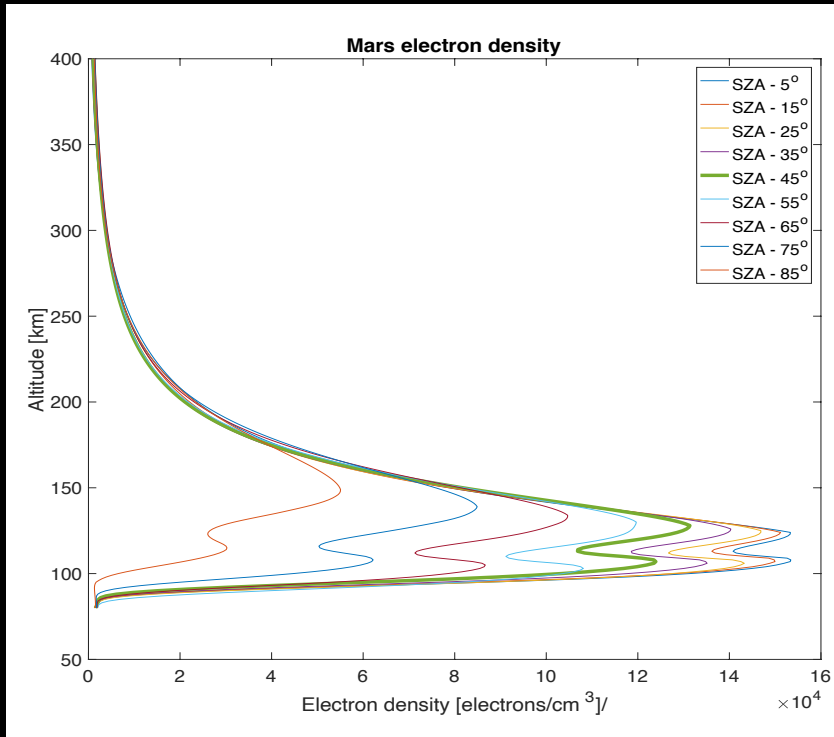


# Simulation of MarCO Radio Occultation

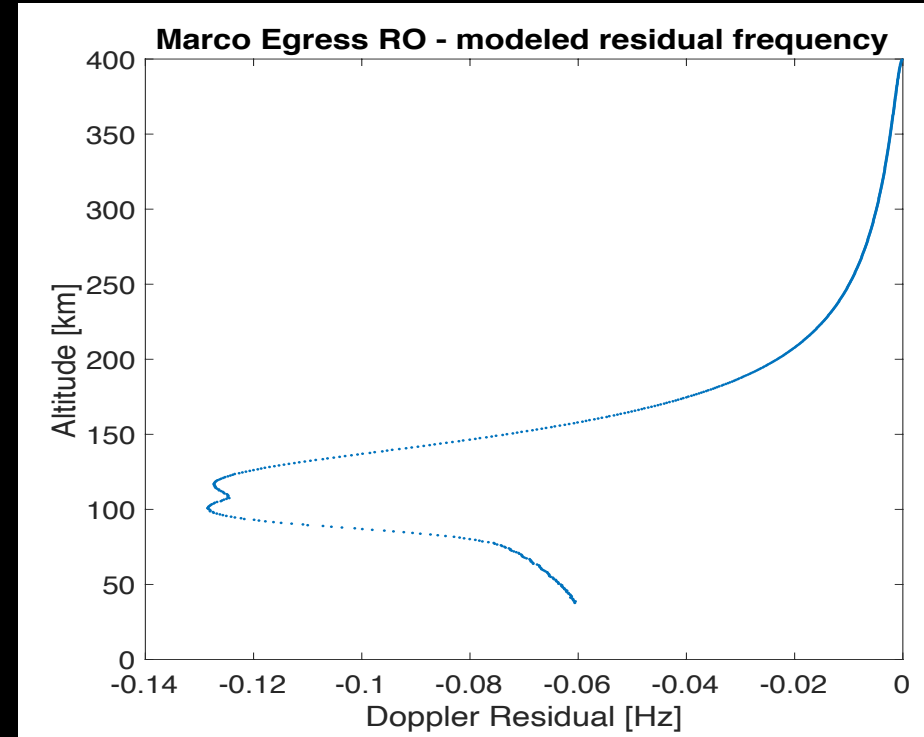


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## Mars Ionosphere Electron Density Profiles



## Simulated MarCO Doppler Residual for Ionosphere RO



MarCO noise level is about  $\sim 0.004$  Hz and Allan deviation  $4 \times 10^{-13}$  (for 1s integration time) which is sensitive to Mars Atmosphere and Ionosphere Occultation.

# Scientific Applications of CubeSat: Radio Science



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Spacecraft	Tracking Mode	Allan Deviation (integration time 1s)
MarCO-A	2-way	4e-13
MarCO-B	2-way	4e-13
Voyager	2-way	3e-11
Huygens	2-way	1e-11
MRO	2-way	5e-13
Galileo Probe	2-way	5e-12
MGS	2-way	3e-13
Cassini	2-way	2e-13



# Summary and Future Work



- An assessment of the MarCO flyby and RO data indicates that the MarCO 2-way data has more stable frequency residual with a noise level about  $\sim 0.005$  Hz and Allan deviation  $\sim 10^{-12}$  (for 1s integration time). Its performance is in the same order of MRO 2 way data.
- Simulation result implies the 2-way MarCO radio signal could have been able to execute an ingress radio occultation of Mars and have a positive detection of the atmosphere and ionosphere.
- The assessment of frequency residual measurements derived from MarCO X-band radio links implies that the 1-way X-band data was not of the quality for Mars Radio Occultation.

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